STS EXHIBIT "I"

Exhibit 300 Attachment 2

Business Case Analysis Report

for

Power Systems Sustained Support

JRC Phase 2

Revalidated CIP F-11: ***Power Systems Sustained Support Program***

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1.0 INTRODUCTION

The Power Systems Sustained Support (PS^3) program is a critical infrastructure program for maintaining and increasing the capacity of the NAS through the replacement of aged, unreliable and obsolete NAS power equipment that support ATC systems.

1.1 Background

The Power Systems Sustainment Program has been a continually funded infrastructure program since its initiation in The 1982 Capital Investment Plan. The plan recognized that the FAA investment in infrastructure needed to be refreshed periodically to perform its intended purpose reliably.

The FAA distributes controls and conditions commercial power as well as provides FAA emergency/standby power to keep the NAS equipment operating. Whenever outages or anomalies occur on the commercial power grid, the FAA provides conditioning and back-up power. The FAA's PS^3 Program

- Conditions incoming power to maintain a consistent voltage, necessary for optimal performance of the increasingly sensitive microprocessor technologies being used by NAS equipment;
- Provides for the protection and safe operation of the NAS power infrastructure during lightning storms and other power surges;
- Maintains an uninterruptible supply of power for NAS facilities and equipment, both through connections to the primary grid and through seamless transitions to back-up generators when the primary grid is lost.

These objectives are accomplished by replacing equipment as it ages and becomes unreliable and obsolete. The NAS $2.4 B power system infrastructure is reaching the end of its service life at a rate of $53.7 million per year. Projects are given priority according to their criticality to NAS operations and deferability. Major PS^3 program elements include replacement of:

- Expended batteries for emergency power and power-conditioning systems
- Aged uninterruptible power systems (UPS)
- Obsolete engine generators
- Deteriorated underground power cable
- Deteriorated lightning protection and grounding systems

NAS ATC equipment and facilities fund the initial purchase and installation of all power systems that they require. After the equipment has been deployed or the facility has been commissioned, PS^3 provides replacement of the power systems as their components become obsolete and unreliable.

2.0 MISSION NEED AND REQUIREMENTS

2.1 Mission Need

As stated in the memorandum for Revalidation of CIP F-11, Power Systems Sustained Support (PS^3) Program, dated May 19, 2005, quality power is a fundamental component of the NAS infrastructure, and the PS^3 program is the key element in ensuring that current and future power requirements of the NAS are met. The FAA cannot rely solely on commercial power sources to support NAS facilities. In recent years, the number and duration of commercial power outages have increased steadily, and the trend is expected to continue into the future (see Benefits Analysis, Section 5.2). Reliable standby power systems must be in place to maintain the integrity of the NAS during commercial power outages.

Much of the FAA's power infrastructure is operating beyond its service life. As the average age of the infrastructure has increased, its availability has decreased. The infrastructure has also become difficult to maintain because parts are difficult to obtain.

In addition to reliable standby power, the increasingly microprocessor-based NAS requires cleaner and more stable power than it has in the past. New equipment is sensitive to voltage and frequency fluctuations. To provide clean and stable power, NAS power systems must be continually updated to comply with equipment manufacturers' power requirements, standards of tolerance, *the National Electric Code* (NEC), the *National Lightning Code* (NLC), and *Occupational Safety and Health Administration* (OSHA) regulations.

2.2 Requirements

PS^3 requirements were established based on the mission need documented in Revalidation of CIP F-11. Requirements are based in several considerations, including:

- Lightning and transient noise voltage resistant power in accordance with Institute of Electrical and Electronic Engineering (IEEE), NEC, and OSHA standards.
- Appropriate OSHA, Lightning Protection Council (LPC), and National Fire Protection Association (NFPA) standards in grounding, bonding, and lighting protection, and electrical wiring systems for FAA facilities.
- A secure data transmission path for Remote Maintenance Monitoring (RMM) and security measures in place at all power sites.
- Adherence with Federal and State environmental regulations.
- Adherence with installation methods to mitigate the potential of seismic events.
- NAS operational availability of quality power at all times.

A summary of some of the key, high-level system requirements is provided below. For a detailed requirements description refer to the *Initial Requirements Document for Power System Sustainment and Support Programs (PS^3).* Power system service is classified as defined in NAS SR-1000, *FAA NAS System Requirements Document.*

The PS^3 systems shall be able to:

- Provide critical power systems to mission critical priority services that, if lost, would prevent the NAS from exercising safe separation and control over aircraft. Critical power distribution systems operate for the uninterrupted control of air traffic by providing highly reliable conditioned power. Critical power has a reliability, maintainability, and availability (RMA) of .999998.
- Provide essential power systems to services that, if lost, would reduce the capability of the NAS to exercise safe separation and control over aircraft. Essential power distribution systems supply power to environmental and operational services that are required to sustain NAS critical systems/equipment. Essential power has a RMA of .9998.
- Provide routine power systems to services that, if lost, would not significantly degrade the capability of the NAS to exercise safe separation and control over aircraft. Building services power systems supply power to NAS systems/equipment that can be shed without major or immediate impact on air traffic operations. Routine power has a RMA of .998.

3.0 PERFORMANCE GAP

A performance gap of increasing ATC delays due to electric power loss to ATC equipment must be avoided. The loss of electrical power is a result of the deteriorating commercial power grid and the chronic under funding of the NAS power systems infrastructure. Under funding of power system investment reduces system reliability and results in increasing vulnerability to NAS operations.

The primary source of electrical power to the NAS is commercial power, which the FAA distributes. However the number and duration of commercial power outages and short-term power quality fluctuations have increased steadily over the past five years. This trend is expected to continue in the future due to increasing demand and lack of national grid investment funding. The FAA emergency/standby power systems are also suffering from under funding. During the period from FY1999 to FY2004, there were 1,640 outages directly caused by engine generator failures and 4,480 outages indirectly caused by engine generator failures. Since outages will continue, the power system infrastructure must be ready to assume the electric power requirements when commercial power fails. At the same time, new electronic equipment being fielded (e.g., STARS) requires a higher degree of power quality to operate reliably.

The root cause of equipment power outages is the increasing inventory of power systems equipment that is beyond its service life. Of the $2.4 billion NAS power system infrastructure, $1.2 billion (50 percent) is beyond the equipment's service-life. This backlog of out-of-service-life equipment is growing by $53.7 million (2 percent) annually. Along with this backlog growth, the existing extensive backlog continues to get older and less reliable each year. Reliability of equipment decreases 8 percent per year when operating beyond its service-life.

The FAA must maintain the current ATC system capacity by replacing unreliable power system equipment to avoid future increasing and extended power outages and service interruptions. Some troubling statistics:

- Of 77,121 NAS batteries, 20 percent require replacement annually
- Of 587 uninterruptible power systems, 16 percent exceed their 10-year service life
- Of 21 Air Route Traffic Control Center power systems, 100 percent require sustainment to maintain service life
- Of 4,942 Lightning Protection/grounding systems, 25 percent require sustainment
- Of 461 DC Power systems, 8 percent require replacement annually
- Of 3,797 NAS engine generators, 75 percent exceed their 20-year service life
- Of 517 airport NAS equipment power cables, 56 percent are beyond their service life

To address these sustainment requirements, the Power Systems Office is requesting annual funding of $60.0 million (in constant dollars) by 2011 incrementally increased to cover the annual backlog growth. The program office requests that the additional annual funding be incrementally increased to the target level over a 5-year period for orderly workload growth planning.

3.1 Criticality/Impact of PS^3

The NAS power systems are critical to the operation of the NAS air traffic control systems. Without NAS electrical power, air traffic control electronics are rendered inoperable and air traffic is delayed.

The 6,120 power-related outages from FY1999 to FY2004 represent a total of 59,769 hours where back-up power was not available. The interruption of primary power when backup power is not available during this time resulted in flights being kept on the ground, placed in airborne holding patterns or re-routed to other airports, creating delays and other costs to airlines and passengers. These delays are not confined to the departure airport but ripple through the NAS, creating additional delays at destination airports. A power interruption lasting less than a second causing a loss of ATC equipment functionality may disrupt flight schedules for a number of hours throughout the NAS.

The impact of power disruptions will become increasingly severe as new, more sophisticated ATC systems requiring a significant increase in reboot recovery times are fielded. An investment analysis shows that $53.7 million is needed to simply sustain services at their present level. However, this status-quo approach does not take into consideration that the $1.2 billion in equipment already beyond its service life will continue to age and grow less reliable. Sustainment services must be expanded to cover this increasing loss of reliability. Currently, due to severe budgetary constraints, the program is scheduled to receive only $39.7 million for FY05 and has been approved for only $45 million in FY 2006 and $38 million in FY07. These amounts are below the level required to prevent further deterioration of the NAS infrastructure. The PS^3 program will correct this, ramping up funding by an additional $5M over the annual backlog growth rate per year to $60.0 million (in constant dollars) by FY 2011 to expand equipment replacement.

4.0 LIFE CYCLE COST ANALYSIS

The F&E cost inputs for the alternatives examined during the investment analysis were based on current contracts (UPS: Powerware: GS-07F-7465C, Mitsubishi Electric Automation, Inc.: GS-07-9526G; DC Power Systems: Marconi Communications Federal, Inc. contract: DTFAWA-03-D-03003; EGs: Kohler contract: DTFA-02-01-D-06602), actuals, RSMeans Electrical Cost Data, 26th Annual Edition, 2003, and input from Subject Matter Experts (SMEs). All costs were risk-adjusted using Crystal Ball, a risk analysis software package, which is used to calculate a high confidence cost estimate. Crystal Ball uses Monte Carlo Simulation, a statistical sampling technique, to incorporate the risk ranges and arrive at a cost estimate considered high confidence value.

The F&E cost estimate model was constructed using Version 4.0 of the FAA Work Breakdown Structure (WBS). Once the F&E cost estimate model was populated with the available unit cost data, the program office provided four funding level alternatives to be estimated along with subsystems prioritization. The quantities of equipment purchased for each alternative were derived subject to the funding levels and subsystem priorities. Once the F&E estimates were complete, the equipment quantities were given to the Ops estimator.

The Ops cost estimate was developed using a variety of techniques, including cost build-up using salaries and FTE requirements, compiling actual costs of items like logistics costs, and historical cost factors for areas such as System Management Office overhead and Academy Maintenance.

Risk was applied to all WBS elements. Depending on the level of detail collected in compiling the estimate, risk ranges on WBS elements ranged from (-)10% to (+)20%. All site level FTEs for legacy system maintenance ranges were (-)10% (+)15%, and for all new systems the most likely value was considered as the high range and (-) 5% was used for the low range. WBS 5.11.2 utilities risk ranges used were (-) 5% (+) 20%.
Crystal Ball was used to develop the high confidence estimate.

The life cycle cost estimates are summarized in Tables 1, 2, 3, and 4 (risk-adjusted current year $M). The analysis timeframe is from FY06 – FY-25.

Table 1. Alternative 1 CIP constrained funding level – Backlog is not retired

Alt 1 CIP	FY06	FY07	FY08	FY09	FY10	FY11	FY12 - 25	Total
F&E	$ 40	$ 38	$ 57	$ 65	$ 60	$ 60	$ 984	$ 1,304
O&M	$ 81	$ 85	$ 89	$ 93	$ 97	$ 101	$ 1,937	$ 2,482
Activity 5	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 20	$ 27
Total	$ 122	$ 124	$ 147	$ 160	$ 158	$ 162	$ 2,941	$ 3,814

Table 2. Alternative 2 Preferred Alternative – Retire backlog in 78 years

Alt 2 Pref.	FY06	FY07	FY08	FY09	FY10	FY11	FY12 - 25	Total
F&E	$ 40	$ 38	$ 64	$ 68	$ 74	$ 78	$ 1,300	$ 1,661
O&M	$ 81	$ 85	$ 89	$ 93	$ 97	$ 101	$ 1,937	$ 2,482
Activity 5	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 20	$ 27
Total	$ 122	$ 124	$ 154	$ 162	$ 172	$ 180	$ 3,257	$ 4,171

Table 3. Alternative 3 – Retire backlog in 45 years

Alt 3	FY06	FY07	FY08	FY09	FY10	FY11	FY12 - 25	Total
F&E	$ 40	$ 38	$ 69	$ 78	$ 86	$ 94	$ 1,541	$ 1,946
O&M	$ 81	$ 85	$ 89	$ 93	$ 97	$ 101	$ 1,937	$ 2,482
Activity 5	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 20	$ 27
Total	$ 122	$ 124	$ 160	$ 172	$ 184	$ 195	$ 3,498	$ 4,455

Table 4. Alternative 4 – Retire backlog in 29 years

Alt 4	FY06	FY07	FY08	FY09	FY10	FY11	FY12 - 25	Total
F&E	$ 40	$ 38	$ 77	$ 89	$ 102	$ 114	$ 1,857	$ 2,317
O&M	$ 81	$ 85	$ 89	$ 93	$ 97	$ 101	$ 1,937	$ 2,482
Activity 5	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 20	$ 27
Total	$ 122	$ 124	$ 167	$ 184	$ 200	$ 216	$ 3,814	$ 4,827

Table 5 provides a WBS-level comparison of the cost estimate for each alternative (risk-adjusted current year $M).

Table 5. WBS-level comparison

WBS	Alt 1CIP	Alt 2 Pref.	Alt 3	Alt 4
3.0 Solution Development	$ 774	$ 1,007	$ 1,157	$ 1,314
4.0 Implementation	$ 510	$ 634	$ 768	$ 984
5.0 In-Service Management	$ 2,487	$ 2,487	$ 2,487	$ 2,487
6.0 Disposition	$ 15	$ 15	$ 15	$ 15
Total	$ 3,787	$ 4,143	$ 4,428	$ 4,799
Activity 5	$ 27	$ 27	$ 27	$ 27
Grand Total	$ 3,814	$ 4,171	$ 4,455	$ 4,827

5.0 BENEFITS

5.1 Approach

Subject matter experts[1] agreed that a relationship existed between annual funding levels and mean time between power system outages, or failures (MTBF). Specifically, an emerging relationship was identified between annual cost (in constant dollars) and annual percentage change in MTBF at both terminal and en route facilities over a 20-year life cycle ending in 2025.

[1] Lloyd Harrison and Michael Singer, ATO-W contract support; Michael McVeigh, ATO-P.

The experts agreed that the current PS[3] equipment backlog - representing roughly \$1B of assets - could be maintained at a constant level by spending \$53.7M each year (constant dollar).[2] This level would maintain terminal and en route facility MTBFs at their current values of 0.607 years and 3.55 years, respectively, over a 20-year life cycle ending in 2025. The corresponding terminal availability in 2025 would be "three nines" (0.99906). (Availability is defined as the ratio of MTBF to the sum of MTBF and mean time to restore (MTTR) service. The latter is estimated to be five hours, and is discussed in more detail subsequently.) At an \$112M annual cost level ("full funding" scenario), the backlog would be eliminated by 2025, and MTBF would increase at a 24% annual rate. The corresponding terminal availability would be "five nines". If no funds are expended ("worst case" scenario), MTBF is assumed to degrade at approximately 20% annually, to commercial power availability (a single "nine") by 2025.[3] (En route facilities have roughly an extra "eight" of availability.) Letting x represent annual cost, and y represent annual percentage change in MTBF, a curve can be fit through the above three points using the equation $x = -0.0058y^2 + 2.5687y + 53.7$. The fit is nearly linear, as can be seen in Figure 1 below. The figure also plots 2025 terminal availabilities against annual cost.

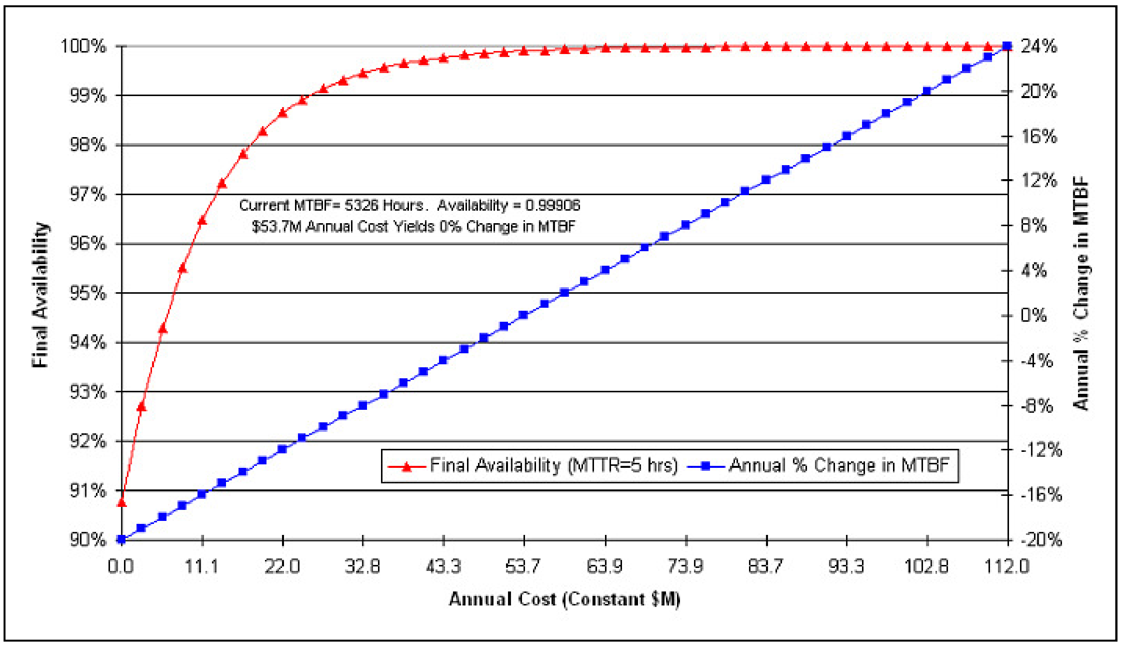

Figure 1. 2025 Availability and Annual Percent Change in MTBF versus Annual Cost

MTBF changes are linked to benefits through the following mechanism: power outages at terminal and en route facilities delay aircraft, by reducing the capacity of affected airports to accept takeoffs and landings.[4] During 2004, 328 aircraft were delayed due to power outages,

[2] The bulk of the backlog consists of engine generators, assuming their ages are distributed uniformly over a 20-year life, 5% must be replaced each year to prevent backlog growth.

[3] Again, a power-conditioning battery has a five-year service life, implying a 20% annual failure rate if not replaced.

[4] Terminal and en route hourly operations capacities are reduced to 36% and 18% of their nominal values, respectively for the duration of the outage. STARS outages are a special case: hourly arrival capacity is reduced to a fixed 46 operations if the outage is of short duration (6 minutes - this occurs 90% of the time); 10 operations if the outage is of long duration (3 hours). The STARS data follow discussion with Michael McVeigh and are consistent with the assumptions for the impact of equipment outages on airport capacity contained in the June

corresponding to 14,760 minutes of delay.[5] Delays are monetized via aircraft direct operating cost (ADOC) and Passenger Value of Time (PVT); details are discussed subsequently in the Output Analysis section. If MTBF is reduced, outages increase - and other things being equal, delays are directly proportional to outages. The annual outage rate, λ is the inverse of MTBF. The baseline λ is about 1.6 for terminal facilities and 0.3 for en route facilities. If MTBF is reduced by approximately 10% annually, λ will approximately double each seven years, so that the outage rate and hence delays will increase eightfold over 20 years.

The team exploited the above relationships to compute life cycle benefits parametrically (details provided in subsequent sections). Annual percentage changes in MTBF were stepped from –20% to +24% in increments of 1%. For any given step, the total minutes of delay and corresponding monetized value were computed. The monetized value was compared to its worst case counterpart (at the –20% annual change in MTBF step - approximately $8.6B in constant dollars). The difference was the cumulative benefit in constant dollars associated with the given step. For example, the monetized value associated with the 0% MTBF step is approximately $300M. Subtracting this value from $8.6B yields $8.3B as the cumulative benefit associated with the 0% MTBF step and its corresponding annual constant dollar cost stream as determined from Figure 1. This benefit represents the cumulative savings achieved in avoided aircraft delays compared to the worst-case scenario. Cumulative benefits can be compared for different MTBF steps. The advantage of this parametric technique is that it isolates the comparisons from possible future changes in the cost estimates - benefits remain unchanged if the MTBF steps remain unchanged, even if different annual cost curves are fit to the steps. Only the NPV need be adjusted in this case.

5.2 Modeling

As previously indicated, if all other factors were to remain the same, then mean cumulative benefits - if not the full benefits distribution - corresponding to different funding levels could be computed using Figure 1 and the scaling formulas discussed above. However, air traffic operations (demand) increase with time, according to the Terminal Area Forecast (TAF). Similarly, airport capacities increase as runways are added. Additionally, high confidence benefits (20^{th} percentile) are desired, not merely mean values. The full distribution of delays in any given year involves a convolution of several distributions - the Poisson-distributed number of outages for the year (rate λ as discussed above); the uniformly distributed starting time of each outage within a day; the distribution of hourly demand at airports over the day; the exponentially-distributed duration of each outage (MTTR); and so on. ATO-P Operations Research applied the System Outage Disruption Model (SODM) Monte Carlo simulation model to similar problems over the past several years.

SODM is an abstraction of reality and makes simplifying assumptions. The model calculates delays associated with arrival queues, which build up during periods of constrained capacity associated with terminal and en route facility equipment outages. These outages affect

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2000 TRACON Risk Study report by Futron Corporation, prepared for Air Traffic System Development Integrated Product Team for Terminal.

[5] Terminal facility outages delayed 91 of these aircraft; counts via AFTechNet. Each such aircraft is assumed to be delayed for 45 minutes on the average. See below for more details.

operations at 37 of the larger U.S. airports. SODM does not explicitly model delays at all of the roughly 20,000 U.S. airports, nor does it explicitly address departure delays. Instead, the minutes of historical delay in the baseline year (2004) are compared to the minutes of delay generated by SODM for that same year. The ratio of the two quantities is used as a calibration factor, which is applied to SODM modeled delay minutes in future years.[6] Note that if an outage occurs and is repaired during a period of light demand at an airport, no queues may build up at that airport and no delay will be incurred. The following section addresses SODM model inputs in more detail.

5.3 Data Collection

5.3.1 System Availability I: NASPAS – Outages Greater Than One Minute

The benefits team calculated the current availability baseline using historical PS^3 data from the National Airspace System Performance Analysis System (NASPAS). The NASPAS includes equipment outages filtered according to National Airspace Performance Reporting System (NAPRS) criteria from the Maintenance Management System (MMS) from 1988 to the present. These outages are defined as events with durations greater than 1.0 minute. Each outage is assigned a cause code that identifies the primary source of the outage. Commercial Power outages and Standby Power outages are assigned codes 82 and 83, respectively. Filtering the data further to annual levels allowed the benefits team to calculate the historical change in the number of annual outages. These determinations result in a .999531 baseline availability for terminal power systems services and a .99992 baseline availability for en route power systems services, for MTBFs of 0.607 years and 3.55 years respectively and an MTTR of 2.5 hours. MTBF and MTTR are discussed further in the Assumptions section below.

5.3.2 System Availability II: Standard Terminal Automation Replacement System (STARS) Segment – Outages Less Than One Minute

FAA Technical Operations Services[7] provided a database containing over 80,000 records across six years representing outages lasting less than one minute in duration (hereinafter referred to as "short-duration outages"). The power systems team identified these records as hidden problems masked by the one-minute rule applied to outages via NAPRS. Such occurrences, although brief, are assumed to have a critical impact on power-sensitive STARS equipment.[8] The benefits team filtered this database, and found 813 records defined as power-related events that would induce a STARS outage. These records corresponded to 149 code 82/83 events and 664 code 87 events, all at 230 sites over a 5.6-year period, which equates to approximately 0.63 outages per site. Per direction from subject matter experts, the benefits team assumed that 100% of these anomalous events would have enough of an impact to affect STARS. Accordingly, the baseline annual STARS short-duration outage rate is taken as 0.63 per STARS site. The corresponding STARS MTTR is discussed further in the Assumptions section below.

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6 See also the SODM User's Guide.

7 Via Jady Handal, ATO-W.

8 Subject matter experts asserted that the STARS system is highly sensitive to small power anomalies less than one minute in duration and will experience a disruption of service. These small power anomalies are often buried under volumes of more visible events and indicate a worsening problem for modernized NAS equipment.

5.3.3 Baseline Delay: AFTechNet

The benefits team analyzed data contained in AFTechNet that provides flight delays, represented as the number of aircraft, corresponding to historical terminal and en route equipment outages. A query for power systems-related delays returned data from 1996 to 2003. Terminal and en route outages delayed 91 and 237 flights per year, respectively, on the average. Almost all of these flights were delayed arriving or departing - a negligible fraction was delayed en route.[9]

5.3.4 Traffic Demand

Airline Service and Quality Performance (ASQP)

The benefits team gathered historical hourly traffic demand profiles from ASQP. The hourly ASQP data by airport is stored in a database called Performance Monitoring and Analysis Capability (PMAC) in the Operations Research Laboratory (ORLAB). This data allows the model to evaluate the impact of an outage based on its stochastic start time and duration.

TAF

To project future delays, the benefits team consulted the TAF growth rates for 37 airports. The TAF contains airport demand growth rates from 2005 to 2020. From 2020 to 2025, the benefits team uses a Microsoft Excel generated straight-line growth rate dependent upon the historical growth trend. This metric is applied multiplicatively to the hourly demand when developing delay results for future years.

5.3.5 Airport Capacity: PMAC

The benefits team extracted current and projected airport capacities from the PMAC database. The capacities were originally input into the database from a series of controller interviews and technical specifications. Capacities influence the number of delays occurring when they are reduced during an outage.

5.3.6 Standardized Economic Values

Assigning economic benefits to avoided flight delays required the team to apply the economic values for ADOC and PVT. The following costs were applied to the avoided delay benefits:

- Airborne delay: $50/minute
- Ground Delay: $25/minute
- PVT: $28.60/hour[10]

[9]For example, a query for standby and primary power outages in 2003 yielded a 53/280/5 split for arrivals/departures/en route delays, respectively. Note that there are approximately five departure delays for each arrival delay.

[10]Per *FAA Office of Aviation Policy and Plans (APO).*

5.4 Assumptions

This section documents the assumptions gathered from subject matter experts, qualitative data analysis, and programmatic details. These assumptions are converted into numeric terms and incorporated in the SODM model.

<u>System Life Cycle</u>

The benefits team calculated benefits of avoided user delay for 2005 until 2025, corresponding to the life cycle used in the power systems investment analysis.

5.4.1 MTTR

Power systems' MTTR in the terminal and en route areas is historically estimated at 2.5 hours per outage.[11] This value reflects current NAS equipment profile dependencies on power systems. However, the benefits team increased this value to 5.0 hours and redefined MTTR specifically as the MTTR service with the assumption that future NAS modernization equipment is more sensitive to power outages and is more severely impacted during an outage. Although power components may be restored quickly, the affected services may not be fully restored as readily as previously stated.[12] To model these effects, the benefits team increased the MTTR to its maximum level in the year immediately following the base year.

The STARS impact segment of this analysis assumes that 90% of the power-induced STARS outages have a MTTR of 0.1 hours. The remaining 10% of the power-induced STARS outages have a MTTR of 3.0 hours.

5.4.2 Funding and Availability

<u>Funding and Availability – Terminal Power Services</u>

Estimating delays for the baseline and improved systems required developing assumptions regarding the current and future levels of performance given a level of funding. The initial assumptions for terminal power services are based on three distinct levels of power service, each listed with their target availability:

- **Critical service = .99999 minimum:** Should power systems become funded for 20 years at a level to eliminate the current backlog and backlog growth, all systems would improve to critical service in 2025. This best-case scenario equates to a +24% annual improvement in MTBF until 2025. This best-case scenario would eliminate the current backlog of $1.0B over 20 years.
- **Essential service = .999 minimum:** The essential service level matches approximately the current power systems' performance with current levels of backlog and no backlog growth.

[11] This same value was used in the previous Power Systems investment analysis study

[12] To cite one anecdotal incident, the "UNIX network" associated with a relatively short-duration STARS power outage required roughly five hours to restore to full service.

- **Commercial service = .9 minimum:** Should power systems receive no funding over 20 years, the MTBF would degrade annually at –20% and operate at commercial service in 2025.

Achieving each of the three levels of power service by the final life cycle year 2025 requires adjusting our baseline MTBF values on an annual basis until the year 2025. Using the baseline terminal level MTBF of .607 years, the required annual MTBF improvement/degradation to achieve each service level, given an assumed increased 5-hour MTTR, is given in Table 6 below:

Table 6. Power Service Levels, 2025 Availabilities and Annual MTBF Percent Changes

Power Service Level	Desired Availability in 2025	Required Annual MTBF % Change
Critical	.99999	+24%
Essential	.999	0%
Commercial	.9	-20%

As shown previously in Figure 1, 2025 availabilities were calculated for intermediate MTBF steps, in increments of 1%.

Funding and Availability – Center and STARS Power Services

For a given level of funding implying a given terminal services annual percentage change in the MTBF step, the same step was applied to center services as well.

The steps were also applied to STARS to estimate the change in the number of per-site short-duration power outages.

5.4.3 Capacity Reduction

Simulating flight delays requires assigning a capacity reduction to the airspace. The benefits team consulted the previous (2000) Power System Investment Analysis Report (IAR), which uses a 36% capacity during a terminal power outage and an 18% capacity during an en route power outage.

The STARS impact segment of this analysis assumes a fixed reduced capacity of 46 aircraft per hour for the 0.1 hour-MTTR STARS outages, and a fixed reduced capacity of 10 aircraft per hour for the 3.0 hour-MTTR STARS outages.

5.4.4 Downstream Effect

Late flight arrivals accrue a delay by exceeding their scheduled arrival time; however, delays also affect subsequent flight legs and incur cancellations and diversions. To account for this effect, known as the “downstream effect”, a multiplier of 1.8 is applied to some delays, as discussed in detail in the Output Analysis section.

5.5.5 Baseline Delay

The team applied an average multiplier of 45 minutes delay per flight to the historical counts in AFTechNet of flights delayed by terminal and en route equipment power outages. This yielded baseline delays of 4,114 and 10,645 minutes due to terminal and en route equipment outages, respectively, in 2004. Furthermore, the team used a departure-to-arrival ratio to monetize the impact of delays in flight and on the ground. The assumption was made that for every five departure delays, the system experiences one arrival delay.[13] Departure delays were assumed to be ground delays; arrival delays were assumed to be airborne delays. Thus, 5/6 of the delay was attributed to ground and 1/6 attributed to airborne. These values were used in developing the calibration factors used to map modeled delays due to equipment outages to NAS-wide delay, which could be monetized, as discussed previously in the Modeling section.

The benefits team found no historical delays related to short-duration power outages affecting STARS. To estimate potential airspace delay per STARS site in the baseline year, the benefits team stochastically modeled the impact of assumed STARS outages at the 37 airports in the SODM model, using the STARS parameters previously described. The mean delay was then divided by 37 to obtain a mean per-site delay; this was scaled for each year by the number of STARS sites. The latter quantity ramped up to 51 Phase-1 sites in 2007 according to the STARS JRC implementation schedule.

5.5.6 General Formulas

<u>*MTTR*</u>

The MTTR is defined as the time to restore service following system failures that result in a service outage. More specifically, the benefits team uses the MTTR for unscheduled outages only. Unscheduled MTTR is calculated as:

$$MTTR = \textit{Total Unscheduled Outage Time} / \textit{Total Number of Unscheduled Outages}$$

<u>*MTBF*</u>

The MTBF is defined as the average time during which all parts of the item perform within their specified limits. More specifically, the benefits team uses the MTBF for unscheduled outages only. MTBF is calculated as:

$$MTBF = (\textit{Maximum Available Hours} - \textit{Total Outage Time}) / \textit{Total Number of Unscheduled Outages}$$

[13] Previous benefits studies have shown the NAS averages five departure delays per arrival delay.

Availability

Availability, A_o (unscheduled outages only) is defined as: $A_o = MTBF/(MTBF+MTTR)$.

For a more detailed analysis of the Power Systems Sustained Support Benefits Assessment see the *Benefits Basis of Estimate for Power Systems Sustained Support (PS3) Program dated 14 March 2005.*

The life cycle cost and benefit estimates are summarized in Tables 7 through 10 below. The analysis timeframe is from FY06 – FY-25.

Table 7. Alternative 1 Cost and Benefits

Alt 1	2006	2007	2008	2009	2010	2011	2006-2011	2012-2025	2006-2025
F&E	$ 38.8	$ 36.8	$ 53.8	$ 60.3	$ 54.4	$ 52.7	$ 296.8	$ 742.0	$ 1,038.8
Activity 6	$ 1.1	$ 1.1	$ 1.1	$ 1.1	$ 1.1	$ 1.1	$ 6.5	$ 15.3	$ 21.8
Total	$ 39.9	$ 37.9	$ 54.9	$ 61.4	$ 55.5	$ 53.8	$ 303.4	$ 757.3	$ 1,060.7
Benefits	$ 2.2	$ 4.1	$ 6.9	$ 10.5	$ 15.6	$ 21.9	$ 61.2	$ 4,650.9	$ 4,712.1
PV Cost	$ 37.3	$ 33.1	$ 44.8	$ 46.8	$ 39.6	$ 35.9	$ 237.5	$ 315.2	$ 552.7
PV Ben	$ 2.0	$ 3.6	$ 5.7	$ 8.0	$ 11.1	$ 14.6	$ 45.0	$ 1,478.6	$ 1,523.6
Delta	$ (35.3)	$ (29.5)	$ (39.2)	$ (38.8)	$ (28.4)	$ (21.2)	$ (192.5)	$ 1,163.4	$ 971.0
NPV	$ 971.0								
B/C	2.76								

Table 8. Alternative 2 Cost and Benefits

Alt 2	2006	2007	2008	2009	2010	2011	2006-2011	2012-2025	2006-2025
F&E	$ 38.8	$ 36.8	$ 59.8	$ 62.8	$ 66.4	$ 69.0	$ 333.5	$ 980.0	$ 1,313.5
Activity 6	$ 1.1	$ 1.1	$ 1.1	$ 1.1	$ 1.1	$ 1.1	$ 6.5	$ 15.3	$ 21.8
Total	$ 39.9	$ 37.8	$ 60.9	$ 63.9	$ 67.5	$ 70.1	$ 340.1	$ 995.3	$ 1,335.4
Benefits	$ 2.1	$ 4.1	$ 7.0	$ 10.6	$ 16.1	$ 22.8	$ 62.7	$ 4,719.6	$ 4,782.3
PV Cost	$ 37.2	$ 33.1	$ 49.7	$ 48.7	$ 48.1	$ 46.7	$ 263.6	$ 414.3	$ 677.9
PV Ben	$ 2.0	$ 3.5	$ 5.7	$ 8.1	$ 11.5	$ 15.2	$ 46.0	$ 1,503.2	$ 1,549.3
Delta	$ (35.2)	$ (29.5)	$ (44.0)	$ (40.6)	$ (36.7)	$ (31.5)	$ (217.5)	$ 1,089.0	$ 871.4
NPV	$ 871.4								
B/C	2.29								

Table 9. Alternative 3 Cost and Benefits

Alt 3	2006	2007	2008	2009	2010	2011	2006-2011	2012-2025	2006-2025
F&E	$ 38.9	$ 36.8	$ 65.3	$ 71.5	$ 77.6	$ 82.7	$ 372.8	$ 1,162.0	$ 1,534.8
Activity 6	$ 1.1	$ 1.1	$ 1.1	$ 1.1	$ 1.1	$ 1.1	$ 6.5	$ 15.3	$ 21.8
Total	$ 40.0	$ 37.9	$ 66.4	$ 72.6	$ 78.7	$ 83.8	$ 379.4	$ 1,177.3	$ 1,556.7
Benefits	$ 2.2	$ 4.1	$ 7.2	$ 11.0	$ 16.7	$ 23.7	$ 65.0	$ 4,749.0	$ 4,814.0
PV Cost	$ 37.4	$ 33.1	$ 54.2	$ 55.4	$ 56.1	$ 55.8	$ 292.0	$ 490.0	$ 782.0
PV Ben	$ 2.0	$ 3.6	$ 5.9	$ 8.4	$ 11.9	$ 15.8	$ 47.7	$ 1,514.6	$ 1,562.3
Delta	$ (35.3)	$ (29.5)	$ (48.3)	$ (47.0)	$ (44.2)	$ (40.0)	$ (244.4)	$ 1,024.6	$ 780.2
NPV	$ 780.2								
B/C	2.00								

Alt 4	2006	2007	2008	2009	2010	2011	2006-2011	2012-2025	2006-2025
F&E	$ 39.0	$ 36.9	$ 72.6	$ 82.4	$ 91.8	$ 100.7	$ 423.3	$ 1,400.0	$ 1,823.3
Activity 6	$ 1.1	$ 1.1	$ 1.1	$ 1.1	$ 1.1	$ 1.1	$ 6.5	$ 15.3	$ 21.8
Total	$ 40.1	$ 37.9	$ 73.7	$ 83.5	$ 92.9	$ 101.8	$ 429.8	$ 1,415.3	$ 1,845.1
Benefits	$ 2.2	$ 4.1	$ 7.4	$ 11.4	$ 17.4	$ 24.7	$ 67.1	$ 4,769.3	$ 4,836.4
PV Cost	$ 37.4	$ 33.1	$ 60.1	$ 63.7	$ 66.2	$ 67.8	$ 328.5	$ 589.1	$ 917.6
PV Ben	$ 2.0	$ 3.6	$ 6.0	$ 8.7	$ 12.4	$ 16.4	$ 49.1	$ 1,522.9	$ 1,572.0
Delta	$ (35.4)	$ (29.6)	$ (54.1)	$ (55.0)	$ (53.8)	$ (51.4)	$ (279.3)	$ 933.8	$ 654.4
NPV	$ 654.4								
B/C	1.71								

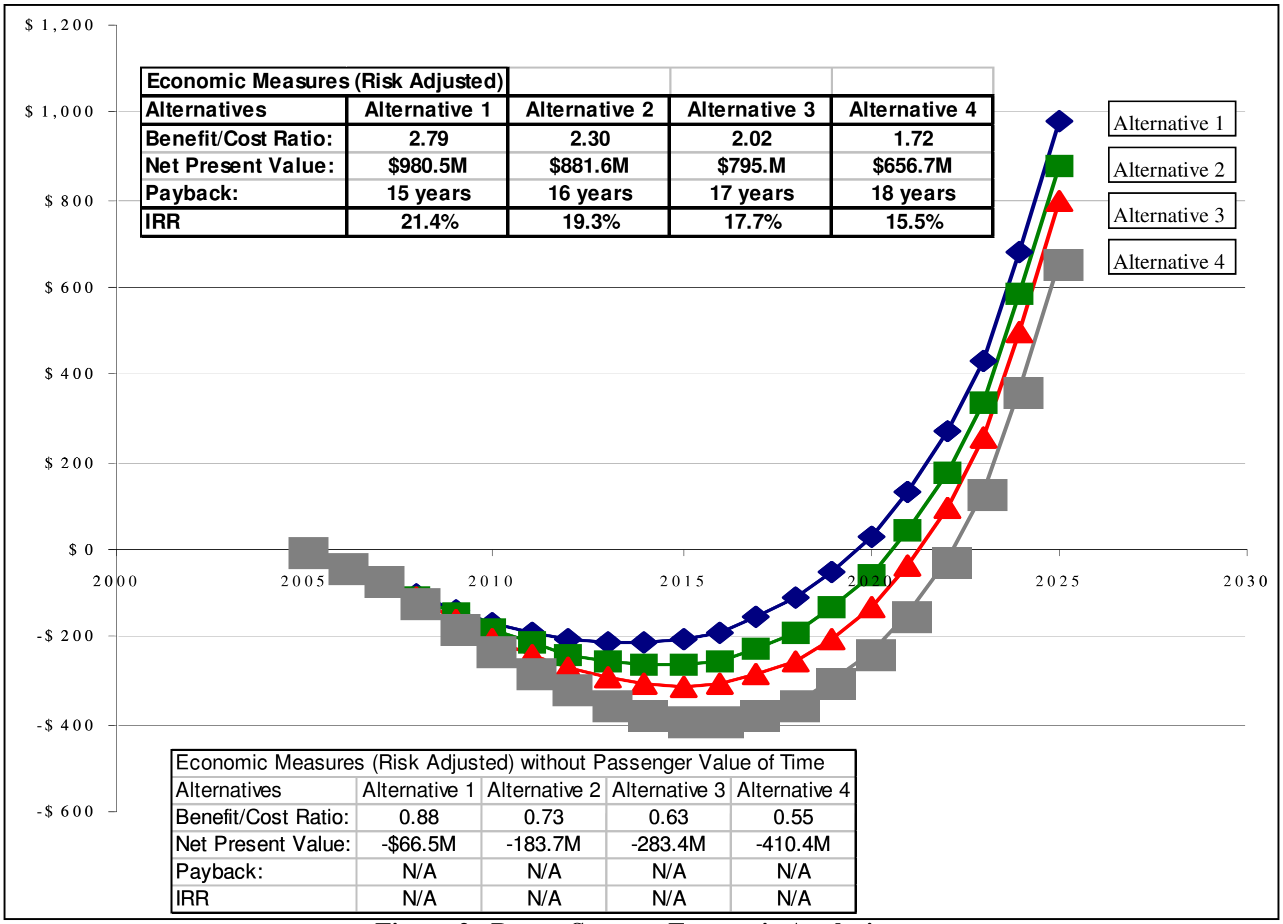
Table 10. Alternative 4 Cost and Benefits

6.0 ECONOMIC ANALYSIS

As part of the economic analysis, the B/C, NPV, and payback period were calculated for the proposed investment. The analysis was based on risk-adjusted cost and benefit estimates.

The B/C ratio and the NPV are calculated to determine whether a program is a viable investment. An investment with a B/C ratio of greater than 1.0 or an NPV greater than zero is economically justified, since the present value benefits associated with the project exceed its present value costs. The payback period is the time it will take for the investment to reach a "break-even" point. More specifically, it is the duration of time that is required for the cumulative NPV to exceed zero.

The results of the analysis for the Power Systems alternatives indicate that this investment is justified with a B/C ratio of at least 1.7 and a NPV of $656M. The project breaks even no later than 2023, as shown in Figure 2 below. As seen below, alternative 1 generates the best return, followed in order by alternatives 2, 3 and 4.



Economic Measures (Risk Adjusted)				
Alternatives	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Benefit/Cost Ratio:	2.79	2.30	2.02	1.72
Net Present Value:	$980.5M	$881.6M	$795.M	$656.7M
Payback:	15 years	16 years	17 years	18 years
IRR	21.4%	19.3%	17.7%	15.5%

Economic Measures (Risk Adjusted) without Passenger Value of Time				
Alternatives	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Benefit/Cost Ratio:	0.88	0.73	0.63	0.55
Net Present Value:	-$66.5M	-183.7M	-283.4M	-410.4M
Payback:	N/A	N/A	N/A	N/A
IRR	N/A	N/A	N/A	N/A

Figure 2. Power Systems Economic Analysis

7.0 ARCHITECTURE IMPACT ASSESSMENT

There is only one Architecture Alternative in this Assessment. This Architecture Alternative is in concert with the last Power Systems JRC. In the assessment of this Alternative, ATO-P (Systems Engineering) found 17 NAS Architecture Operation Improvements (OIs) that need Power System Mechanisms. The Architecture will be updated with the OI links to Power System Mechanisms.

ATO-P concurs with the Power Systems Sustained Support Program with regard to the NAS Architecture. For a more detailed analysis of the Power Systems Sustained Support Architecture Impact Assessment see the *NAS Architecture Impact Assessment (AIA) for the Power Systems Sustained Support (PS3) Program dated 13 June 2005.*

8.0 RISK ASSESSMENT

The Risk Assessment was waived for this investment analysis because of the nature of the program. The Power Systems Sustained Support (PS^3) Program is responsible for acquiring backup power system equipment as needed to replace worn out power system equipment with new replacement in kind equipment.

9.0 SAFETY ASSESSMENT

ATO-P System Safety Office found that the Power Systems Sustained Support program has no system safety requirements. No new safety hazards originate with the power system sustainment program to ATC and navigation services. Hazards currently existing within the NAS are accepted.

10.0 AFFORDABILITY ASSESSMENT

The CIP Alternative was chosen as the preferred alternative. This alternative and this program is considered affordable if overall F&E funding remains at $2.7 billion levels in FY07-11. The current FY07 OST submission, July 26, 2005 CIP, is $2.7 billion. If the OMB Passback reduces budget targets to below $2.7 billion, offsets would need to be found from other programs or funding for Power Systems reduced and deliverables replanned.

Table 11. F&E CIP Funding Profile for Power Systems Sustained Support

Cost (TY)$M	FY06	FY07	FY08	FY09	FY10	FY11	FY12 - 25	Total
CIP	$ 40	$ 38	$ 57	$ 65	$ 60	$ 60	$ 240	$ 560
Power Systems	$ 40	$ 38	$ 57	$ 65	$ 60	$ 60	$ 984	$ 1,304
Delta	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ (744)	$ (744)
O&M	$ 81	$ 85	$ 89	$ 93	$ 97	$ 101	$ 1,937	$ 2,482